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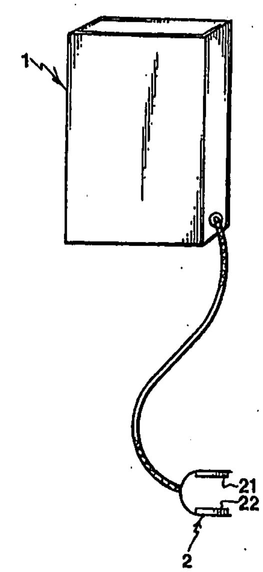
*In English translation (filed in Swedish).*


(54) Title: A DEVICE FOR THE DETERMINATION OF BLOOD SUGAR


(57) Abstract

A device and methods are described for the determination of blood sugar content comprising a measuring part (1) and a sensor part (2). The electric contact surfaces (21, 22) of the sensor part are contactable with either side of a piece of living human tissue having a high capillary blood flow rate for non-invasive determination of the blood sugar content.

# A DEVICE FOR THE DETERMINATION OF BLOOD SUGAR

## Field of the Invention

The present invention relates to a device and a method for the determination of blood sugar content.

## Background of the Invention

Diabetes is a chronic metabolic disorder characterised by insufficient production of the hormone insulin. Diabetes causes fluctuations in the patient's blood sugar content. Serious complications, such as vascular changes which can lead to amputation, blindness and heart and kidney disease, may arise as a consequence of diabetes. The diabetic's loss of or reduced insulin production can be compensated for by means of existing insulin preparations. However, the patient's ability to "feel" his current blood sugar content is also reduced. Today, regardless of the stage of development of the disease, in order to check their blood sugar content diabetics are obliged to use measuring methods which are carried out by means of a blood test and the addition of chemical reagents. Such measuring methods are not available to diabetics for regular checks in everyday conditions. Furthermore, this blood test method provides insufficient therapeutic data for measures adapted to the disease, comprising diet, tablets and insulin. The lack of knowledge about the current blood sugar content means that the fluctuations in the diabetic's blood sugar contents can be considerable, leading to faster destruction of peripheral vessels, etc. In the long term, this leads to extensive medical intervention.

Up-to-the minute knowledge, in various life situations, of the current blood sugar content would substantially improve the diabetic's own therapy with respect to diet, tablet intake, and insulin dosage. A simple, inexpensive and easy-to-use measuring device for the determination of blood sugar, usable in everyday living,



would afford the diabetic an entirely new therapeutic situation.

A biophysical parameter can be determined using either an invasive ("bloody") or a non-invasive ("bloodless") technique. A measuring device, especially for the determination of blood sugar content, is previously known from US-A-5,502,396. This known measuring device is based on the step of arranging a sample on the sensor forming part of the measuring device. This patent specification thus describes a device for invasive determination of the blood sugar content.

A device for non-invasive determination of the constituents of blood is known from WO 97/15227. According to that specification, data representative of the patient's ECG are used for determining the blood sugar content.

US-A-5,119,819 shows a device for non-invasive determination of changes in blood sugar content. With the aid of the device, acoustic speeds are measured in the tissue, which are then related to values of blood sugar content.

GB-2,033,575 describes a device for non-invasive determination of the capillary blood flow rate, in which is provided a means, which is adapted to be held against the patient's body surface, for applying alternating current. Current is carried, at the depth of the capillary bed, along a path between two spaced-apart points. The resulting voltage drop, which is measured along at least part of the length of the current path, is said to provide an indication of the capillary blood flow rate.

## Summary of the Invention

It is an object of the invention to provide a measuring device for the determination of blood sugar content, which is simple, inexpensive, and easy to use, and by means of which diabetics can check their blood sugar content whenever they wish and act accordingly.

A further object of the invention is to provide a method of non-invasive blood sugar content determination.

These objects have been achieved by means of a device of the type stated in the preamble to claim 1, and exhibiting the characteristics stated in the characterising portion of claim 1, as well as by methods of non-invasive determination of blood sugar content according to claims 3, 4, and 5.

The absorption capacity and electrical conductivity of blood in a certain tissue portion, e.g. the fingertip, varies depending on the concentration of glucose in the blood flowing through the tissue portion. This variation can be recorded, amplified, and read non-invasively, without direct access to the blood, in a device comprising a measuring part and a sensor part electrically connected thereto. In connection with measuring, the user places, for example, his finger in the sensor part, whereby an open electric circuit is closed. The reading is carried out spontaneously by means of the sensor part and can take place in most everyday situations. This enables the diabetic to continuously record his current blood sugar content. Having this knowledge enables the diabetic to adjust his diabetes therapy to minimise blood sugar content fluctuations. Especially in the case of IDDM patients (Insulin-Dependent-Diabetes-Mellitus), this is of major importance for the interplay between diet and insulin administration.

It is known that ions, e.g. sodium ions, which are dissolved in the blood are affected by electric fields. The invention is based on the insight that blood sugar molecules have a dielectric effect on, inter alia, sodium ions. As a result, the electrical impedance of a tissue with a high capillary blood flow rate varies with blood sugar content within certain frequency ranges.

From an electrical point of view, closing an open electric circuit by placing a body part with a high capillary blood flow rate between two poles is the equi-



valent of placing an impedance between the poles. As described above, the magnitude of this impedance varies with the blood sugar content in the body part within certain frequency ranges for an applied electric field. Examples of body parts with a high capillary blood flow rate include the fingertips, toes, and earlobes.

Furthermore, the determination of this impedance variation can be integrated with a calibration process based on two or more programmable blood sugar values, determined by means of conventional measuring methods.

According to a first method, the impedance is determined at only one or a few frequencies, which enables very fast and simple measuring. However, it has a limitation in that it is necessary to assume that the molecular composition of the capillary blood is constant in all respects other than the blood sugar concentration. If the number of electrolytes in the blood varies between measurements, it may thus affect the measuring result.

Consequently, according to a second method, the impedance is instead determined at a plurality of frequencies in a broad frequency spectrum. This determination is somewhat more time-consuming, but affords the possibility of compensating for changes in the composition of the blood between measurements.

Sodium chloride (NaCl) is a particularly important component in the electrolytic balance of blood. Even small variations in this concentration can result in major changes in the electrical impedance. The results of initial trials show that the impedance in the frequency range 1-100 MHz is significantly blood sugar dependent, while at around 1500 MHz impedance data is obtained which is linearly dependent on the NaCl concentration, but independent of the sugar content in the blood.

## Brief Description of the Drawings

The invention will be described in more detail below with reference to the accompanying drawings, in which

Fig. 1 is a schematic view of a measuring device according to the invention, showing a measuring part and a sensor part connected thereto, and Fig. 2 is a schematic view of the measuring part included in the device according to Fig. 1.

Description of Preferred Embodiments

As seen in Fig. 2, according to a preferred embodiment, the measuring part 1 shown in Fig. 1 comprises a current supply means 11, an electric circuit 12, a memory medium 13, a microcomputer 14, and means 15 for inputting information to and reading information from the memory medium 13 as well as for reading measurement data. The measuring part 1 is electrically connected to the sensor part 2, which comprises two opposing and spaced-apart electric contact surfaces 21, 22 with a first and a second electric potential. When the user places, for example, his finger between the contact surfaces (poles) in such a way that the contact surfaces abut against it on either side, an electric current, e.g. of a magnitude of 10 mA, flows through it. The impedance between the poles is proportional to the blood sugar content in the blood flowing through the human tissue. In other words, the relationship between the impedance and the blood sugar content can be described by the formula:

$Vg = Ki \times Z$, where

$Vg$ = the blood sugar concentration
$Ki$ = the calibration coefficient of the individual
$Z$ = the impedance in the tissue

The calibration coefficient of the individual is obtained by means of the measuring device through at least two consecutive measurements at known blood sugar contents of the individual. These values, from a blood sugar determination of the capillary blood in a chemical blood sugar meter, are input as reference values to the memory medium 13 in connection with the respective cali-



bration measurements. In connection with the calibration, the blood sugar values should have a minimum difference of 10mmol/1.

The voltage drop across the mass of tissue (the fingertip) placed between the poles is proportional to the blood sugar content of the blood flowing through the capillaries within a specific measurement range, e.g. 2-17 mmol/1. The current measurement value is stated with, for example, one decimal and is expressed in, for example, mmol/1. The electric contact surfaces 21, 22 are located at a fixed distance from each other, which is determined by the individual who is going to use the measuring device. A technical specification is given below as a non-limiting example of a preferred embodiment of a measuring device according to the invention:

Measurement range: blood sugar 2-17 mmol/1.
Accuracy: 0.1 ± 0.05 mmol/1
Measurement time: 1-2 seconds
Calibration difference: minimum 10 mmol/1
Calibration values: two or more.

Components

Measuring part: microcomputer, electric circuit, display, keypad for calibration, batteries and fault indicator.
Dimensions: height 20 x width 8 x depth 4 (cm)
Display: LCD
Operating temperature: -5 - 40°C
Connecting cord with measuring part: (for fingertip)
Cable length: 40 cm
Sensor part: diameter 10-25 mm (20 different dimensions)
Depth: 20 mm, conical with a flat bottom.

According to another embodiment of the invention, the current supply means 11 comprises a multi-frequency generator, which generates a broad frequency spectrum within the frequency range of 0.1-2000 MHz. An electric field is generated between the contact surfaces 21, 22 (the poles). For the tissue placed between the poles, electrical impedance is determined with the aid of the

means 15 for at least a part of the frequency components generated by the multi-frequency generator. This impedance spectrum is compared in the microcomputer 14 with spectra included in a spectrum library stored in the memory medium 13. This spectrum library has been created by determining impedance spectra for known blood sugar concentrations of the patient, the loads being obtained by means of conventional methods. With the aid of the microcomputer 14 the part of the spectrum which contains the "blood sugar signal" is identified and other parts of the spectrum are utilised to compensate for changes in the composition of the blood between measurements. Subsequently, a value for the blood sugar content of the blood is calculated. The measuring instrument generates a warning signal if the microcomputer 14 detects signals for which it cannot compensate. These signals may represent external interference sources such as the patient's medicine intake.

The above description relates to the determination of the blood sugar content of human blood, but it will be appreciated that the invention is also applicable to the determination of the blood sugar content of blood from other mammals.



CLAIMS

1. A device for the determination of blood sugar content, comprising

a measuring part (1), which comprises a current supply means (11), an electric circuit (12), a memory medium (13), a microcomputer (14), and means (15) for inputting information to and reading information from the memory medium (13), as well as for reading measurement data;

a sensor part (2), which is electrically connected to the measuring part and comprises at least two opposing, spaced-apart electric contact surfaces (21, 22)

c h a r a c t e r i s e d in that

the electric contact surfaces (21, 22) of the sensor part are contactable with either side of a piece of living human tissue with a high capillary blood flow rate for non-invasive measuring of the blood sugar content.

2. A device according to claim 1, wherein the current supply means (11) comprises a multi-frequency generator.

3. A method of non-invasive determination of blood sugar content, comprising the steps of

calibrating a measuring device by inputting at least two reference values;

arranging at least two electric contact surfaces on opposite sides of a body part having a high capillary blood flow rate;

applying a predetermined voltage between the two electric contact surfaces;

reading the current between the two electric contact surfaces; and,

by utilising the reference values, converting the read current value to a value of the blood sugar content.

4. A method of non-invasive determination of blood sugar content, comprising the steps of

calibrating a measuring device by inputting at least two reference values;

arranging at least two electric contact surfaces on opposite sides of a body part having a high capillary blood flow rate;

applying a predetermined current between the two electric contact surfaces;

reading the voltage between the two electric contact surfaces; and,

by utilising the reference values, converting the read voltage value to a value of the blood sugar content.

5. A method of non-invasive determination of blood sugar content, comprising the steps of

calibrating a measuring device by inputting at least two reference values;

arranging at least two electric contact surfaces on opposite sides of a body part having a high capillary blood flow rate;

applying an electric field between the two electric contact surfaces;

determining the electrical impedance between the two electric contact surfaces at several frequencies; and,

by utilising the reference values, converting the determined impedance to a value of the blood sugar content.



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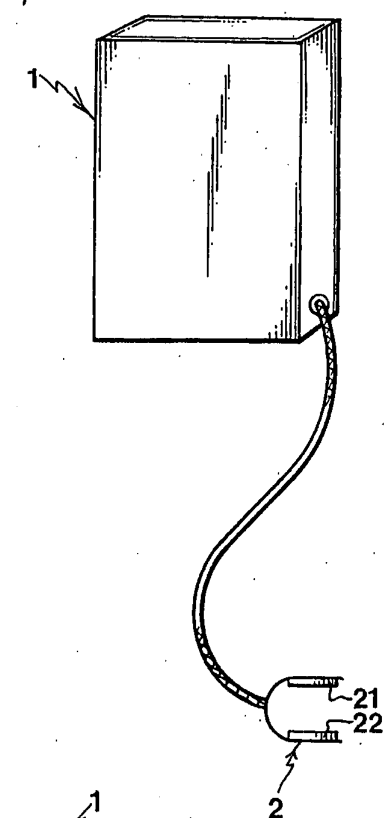


FIG I

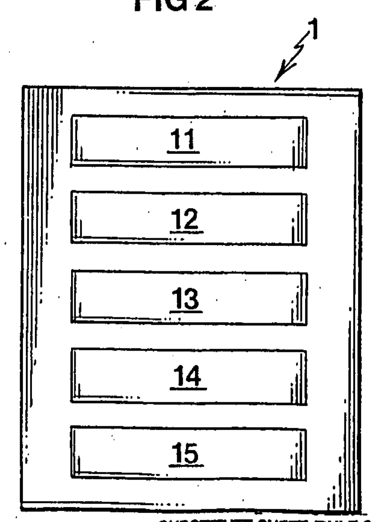


FIG 2

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 99/00294

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC6: A61B 5/00
According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC6: A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | GB 2033575 A (PETER ROLFE), 21 May 1980 (21.05.80), page 3, line 70 - line 115, figure 3, abstract<br>-- | 1-5 |
| A | US 5119819 A (G.H. THOMAS ET AL.), 9 June 1992 (09.06.92), see the whole document<br>-- | 1-5 |
| A | WO 9715227 A1 (MEDTRONIC, INC.), 1 May 1997 (01.05.97), see the whole document<br>-- | 1-5 |
| A | WO 9723159 A1 (CME TELEMETRIX INC.), 3 July 1997 (03.07.97), see the whole document<br>--<br>-------- | 1-5 |

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 23 June 1999 | 03 -07- 1999 |
| Name and mailing address of the ISA/<br>Swedish Patent Office<br>Box 5055, S-102 42 STOCKHOLM<br>Facsimile No. +46 8 666 02 86 | Authorized officer<br><br>Joni Sayeler/AE<br>Telephone No. +46 8 782 25 00 |



# INTERNATIONAL SEARCH REPORT
Information on patent family members

01/06/99

International application No.
PCT/SE 99/00294

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| GB 2033575 A | 21/05/80 | GB 2100864 A,B | 06/01/83 |
| US 5119819 A | 09/06/92 | NONE | |
| WO 9715227 A1 | 01/05/97 | AU 7385396 A<br>US 5741211 A | 15/05/97<br>21/04/98 |
| WO 9723159 A1 | 03/07/97 | GB 9526309 D | 00/00/00 |